

# **Tropical Cyclone Motion Studies**

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## **LONG-TERM GOALS**

The long-term goal is to improve the prediction of tropical cyclone track and structure so that warnings to the Fleet units afloat and ashore are optimized.

## **OBJECTIVES**

(1) Improve tropical cyclone track prediction within the framework of the Systematic Approach to Tropical Cyclone Track Forecasting and (2) Improve understanding of tropical cyclone structure including rapid intensification and extratropical transition.

## **APPROACH**

(1) Utilize the Systematic Approach framework to demonstrate the feasibility of optimizing track forecast guidance. The error mechanisms are isolated from cases of known large 72-h track errors in several tropical cyclone regions and a beta test has been organized to demonstrate that these error mechanisms can be detected in real-time. A detailed special training syllabus is created to assist the forecasters to recognize these error mechanisms and discard erroneous guidance.

(2) Address the Navy need for 120-h track forecasts by improving the early detection of tropical cyclone formation via operational global models.

(3) Utilize a data base of tropical cyclones undergoing extratropical transition in the western North Pacific to document the characteristics and the physical processes involved.

(4) Work with U.S. Weather Research Program to advance understanding of Hurricane Landfall requirements and opportunities, and work with World Meteorological Organization to address global impacts of tropical cyclones.

## **WORK COMPLETED**

(1) An analysis of the clusters of five dynamical model tropical cyclone track forecasts has demonstrated the advantages of selective consensus forecasts. A two-part publication that describes error mechanisms that led to large 72-h track errors in the western North Pacific has been published and these error mechanisms have been found in other models and in other basins. A description has

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been published of a beta test that documented that these error mechanisms can be detected in simulated real-time. The expert system that applied these concepts has been tested operationally with the assistance of a detailed training syllabus that is web-based.

(2) A preliminary study has been completed, and submitted for publication, of the ability of the Navy Operational Global Atmospheric Prediction System to predict tropical cyclone formation, which is a necessary (but not sufficient) condition for meeting the Navy need for 120-h track forecasts even as the cyclone starts.

(3) A Ph.D. dissertation by Peter Klein (LCDR, USN) has utilized numerical model simulations to understand the midlatitude circulation and tropical cyclone contributions in extratropical cyclogenesis. A manuscript has been submitted that summarizes the relative contributions of the midlatitude circulation and the tropical cyclone to extratropical transition. Another Ph.D. dissertation by Nancy Baker (NRL-Monterey civilian) produced an adjoint technique that documents the impact of individual observations on the forecast.

(4) A major symposium was organized for the American Meteorological Society national meeting that focused on hurricane landfall quantitative precipitation forecasting. Other work with the World Meteorological Organization has resulted in a publication describing the rapid cyclogenesis of Supertyphoon Flo during the ONR Tropical Cyclone Motion-90 field experiment.

## **RESULTS**

(1) A journal article (Elsberry and Carr 2000) documents the advantages to be gained in the Systematic Approach by first rejecting dynamical model track forecasts likely to have a 72-h error greater than 300 n mi, which is called a selective consensus track. Even though only five dynamical models are utilized, each has a different initial analysis and different model physics, so that a type of ensemble forecasting is involved. In addition to the expected result that the consensus mean will have a better performance in the average, the spread about the consensus mean also contains information about the accuracy of the mean track. By first rejecting an erroneous track to form the selective consensus, the errors are reduced relative to the non-selective consensus track from an average of all five tracks. The basis for detecting likely erroneous tracks is described in the two-part publication (Carr and Elsberry 2000a,b). The key result is that a relatively small set of conceptual models based on real physical mechanisms that cause tropical cyclone motion, and that the model is not properly handling, explain the large model track errors (Elsberry and Carr 2001). Another publication (Carr et al. 2001) describes the beta test in which Naval Postgraduate School personnel demonstrate a potential for real-time application of these large track error mechanisms. The first objective is knowing when to accept the consensus of the dynamical model tracks and when to question that guidance. The second objective is to recognize a likely erroneous track forecast and eliminate it to form a selective consensus track that is more accurate than the non-selective consensus (Elsberry 2000). A special emphasis during this fiscal year has been the development of a detailed Systematic Approach training syllabus for the Joint Typhoon Warning Center (JTWC) forecasters. This syllabus was delivered in June 2001. Thus far, the JTWC forecasters are achieving an incremental (~ 30 n mi) decrease in 72-h track errors. Only a few years ago, the 72-h error was of the order of 300 n mi.

(2) The Navy requirement for a 120-h track forecast has raised the need to consider when and where a tropical cyclone will form, because the cyclone may reach maturity in 5 days. Furthermore, the early stage cyclone motion forecasts by global models is less accurate than during the mature stage,

especially when the model forms the cyclone in the wrong location. Cheung and Elsberry (2001) have done a preliminary study of tropical cyclone formation in NOGAPS. Although about 70% of the formations are correctly forecast, a disturbing number of false alarms diminish the significance of the correct forecasts. One interpretation is that NOGAPS is too active in forming monsoon-related tropical cyclones.

(3) Advances in understanding the extratropical transition of a tropical cyclone to an extratropical cyclone are summarized in the Ph.D. dissertation by LCDR Klein (2000). The report by E. Ritchie in this volume describes work demonstrating that COAMPS model simulations can reproduce almost all aspects of the cloud evolution during the three transformation steps as Klein found from satellite observations. The dynamical and thermodynamic processes that determine the structure of the tropical cyclone remnants at the end of transformation are documented based on these high-resolution COAMPS simulations. The report by P. Harr in this volume describes another publication by Klein et al. (2001) that uses COAMPS simulations to separate the contributions of the midlatitude circulation and of the tropical cyclone position and motion to the re-intensification stage of extratropical transition.

Other advances in our studies of the extratropical transition are summarized in these reports by Patrick Harr and Elizabeth Ritchie in this volume.

(4) As an Associate Lead Scientist for Hurricane Landfall (HL) in the U. S. Weather Research Program (USWRP), an opportunity exists to integrate and influence the Navy, NOAA, NSF, and NASA research. An implementation plan for the HL component of the USWRP has been presented in several conference venues (Elsberry 2000, 2001). The Second USWRP Science Symposium was arranged in conjunction with the Interdepartmental Hurricane Conference during March 2001, which gave an opportunity for interaction with operational units including the U. S. Navy. Another major activity was the initial organization of a Joint Hurricane Testbed based on the proposed Hurricane Operational Transition center (Elsberry 2001). In addition, I coordinated the evaluation of the first round of JHT proposals that resulted in the funding of nine projects totaling more than \$1 million that are planned to be implemented at the National Hurricane Center within two years.

Another major activity was the organization of a session on hurricane-related Quantitative Precipitation Forecasting. A meeting summary (Elsberry 2001) will be published in the *Bulletin of the American Meteorological Society* that summarizes the overview talks, poster presentations, and panel discussions. Based on this session and other materials, a needs assessment on this topic has been prepared (Elsberry 2001).

A USWRP project on an observing system experiment has been published (Hirschberg et al. 2001). This study demonstrated that greater spatial and temporal resolution along a “picket fence” can affect the mesoscale weather predictions far downstream under certain conditions.

(5) I served on the organizing committee for the World Meteorological Organization Third Comparison of Mesoscale Prediction and Research Experiment (COMPARE) that utilized the ONR Tropical Cyclone Motion (TCM-90) data set. A summary of the COMPARE results on this case of rapid intensification of Supertyphoon Flo has been published (Nagata et al. 2001).

## TRANSITION

The Systematic Approach for track prediction technique has been tested by JTWC with encouraging success so far during the 2001 season.

## SUMMARY

A significant advance has been made in helping operational tropical cyclone forecasters understand when the dynamical model track forecasts are likely to be good, or may contain significant errors and thus should be rejected. Because the error-causing mechanisms are related to real physical processes that cause tropical motion, these errors are not random or chaotic. Averaging the remaining model track forecasts after eliminating the likely poor guidance leads to improved forecasts, and this is being demonstrated by the Joint Typhoon Warning Center this season.

National cooperation among ONR, NOAA, NSF, and NASA in the U. S. Weather Research Program Hurricane Landfall focus is contributing to advance understanding and a transition to operations at the national Hurricane Center. International cooperation with the World Meteorological Organization addresses the tropical cyclone as a global problem requiring a global solution.

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